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Utilization of Maize Cob and Rice Husk ash in manufacturing Paver block concrete for low traffic areas

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ABSTRACT

This paper highlights the results of a study which was conducted on M35 grade cast concrete paver blocks using rice husk ash (RHA) and maize cob ash (MCA) partial replaced with Ordinary Portland Cement (OPC). The replacement for rice husk ash was fixed at optimum 10% ash and maize cob ash was varied from 2.5 % to 10%. Control mix concrete was prepared without any replacement and only with ordinary Portland cement. The basic compressive strength was compared for both i.e. with the specimens exposed to sulfuric acid, nitric acid, magnesium sulfate, and sodium sulfate at the ages of 28, 60, and 90 days. The test results confirmed the attainment of requirement of compressive strength with 5% MCA and 10% RHA. While less changes were observed in durable properties of MR concrete than control mix concrete. It was concluded that MR concrete can be used in lawns, open area, parking areas, low traffic areas, houses, and for manufacturing of perforated blocks/grass concrete paving / permeable concrete to be used for vegetation purposes. It can provide good resistance against sulfuric acid produced by the decomposition of organic matter and convert into sulfuric acid after reacting with moisture present in the soil.

Key words: *Maize cob ash, Rice husk ash, Sulfuric acid, Nitric acid, Magnesium sulphate*

Introduction

Cement concrete paver blocks are easy in molding in various sizes and shapes like I – section, rectangular, round or any other shape. However, the production of cement effects the environment, due to the overutilization of natural resources and the emission of carbon dioxide. The aim of this study was to reduce the cement content in paver block concrete and utilize waste materials i.e. corn cob ash and rice husk ash and to produce environmental friendly concrete paver blocks. This can be achieved when the waste material used serves the purpose of binding materials and the paver concrete blocks attain required strength and durability.

Paver blocks when used in an aggressive environment and in industrial area face the exposure of sulfuric acid, nitric acid, and sulfate attack during their life cycle. When leaves, litter, and other waste materials pile up on the paved road, hydrogen sulfide (H_2S) gas is produced due to the decomposition of organic matter in suitable conditions which further oxidizes into corrosive sulfuric acid (H_2SO_4) and attacks the paver blocks concrete (Joorabchian, 2010). Compounds produced in industries and radicals of nitrates present in artificial manure are responsible for nitric acid formation in water and deterioration of concrete. It is not as harmful as H_2SO_4

(Olusola and Joshua, 2012). Sulfate is normally available in the soil, groundwater, and in wastewater. Utilization of sulfate enrich aggregates, excess of gypsum, sulfate containing water in concrete are responsible for sulfate of sodium (Na_2SO_4), and magnesium ($MgSO_4$) attack (Venkatanarayanan and Rangaraju, 2014).

Rice Husk and Corn cob ash are the two waste materials which are also used as fuel in industries. Thakur *et al.* (2017) found that the 20% replacement of cement with RHA increased the strength after 56 days of curing for M35 grade concrete. Omoniyi *et al.* (2013) also added of RHA with bamboo ash and reported increased surface wear and strength properties of the paver blocks. Gulati *et al.* (2018) blended the ternary of rice husk ash and silica fumes with glass powder up to 20% in cement to gain the strength but reported decreased workability of concrete. Raheem *et al*. (2017) studied the specimens with replacement levels ranging from 5 to 25% cured for periods of 3-56 days and found lower compressive strength at early curing time but the same improved significantly at later age. 10% replacement level showed increased strength as compared to 0% CSA at 28 days curing period. Density decreased with increasing ash content, the water absorption rate increased with increased CSA contents, while abrasion resistance increased with increasing amount of CSA substitutions. The test results revealed that CSA paving stones could attain higher strength than the conventional ones at longer curing periods, due to its pozzolanic reactions. According to Bapat, (2012) increased compressive strength with curing age of the concrete. This increase in compressive strength was due to the pozzolanic reaction in the presence of CCA in concrete. The early strength was as such lesser but increased with an increase in curing age. Better durability of specimens cast with RHA has also been studied under sulfate exposure when the water cement ratio was decreased from 0.58 to 0.47 (Venkatanarayanan and Rangaraju, 2014). The use of 5% RHA in concrete also improved the resistance against nitric acid, (Swetha and Ramana, 2017). 7.5% replacement of cement with corn cob ash in concrete improved the resistance in sulfate environment of 5% diluted magnesium, sodium, and combination of both chemical by reducing the expansion of concrete (Kamau *et al*., 2016).

Aim

It is therefore obvious from above that the addition of both RHA and CSA in the presence of OPC leads to pozzolanic reaction and better durability. The aim of this paper was to find out the optimum replacement level of Ordinary Portland Cement with rice husk and maize cob ash blended concrete which would produce more environmental friendly concrete pavers. Thereafter examined the mechanical and durable properties of paver block concrete using four chemicals; H_2SO_4, HNO_3, $MgSO_4$, and Na_2SO_4 for 90 days.

Experimental

Materials and Method

All the raw materials were collected and properties were examined in order to confirm the codal requirements. M35 grade mix was designed as per IS code 10262:2009 on the basis of the properties of the raw materials. Paver blocks were cast for using RHA and MCA as a replacement of cement in M35 grade concrete. 0%, 10% RHA and 2.5% MCA, 10% RHA and 5% MCA, 10% RHA and 7.5% MCA and 10% RHA and 10% MCA replacement levels were adopted for this purpose. After 24 hrs. of casting, I – shaped paver blocks were cured in potable water. The compressive strength of all paver blocks was determined after 7, 28, and 56 days and optimum replacement level was obtained. Again, I – shaped Paver blocks were cast with an optimum replacement level in M35 grade concrete. Mechanical and durable properties were determined by submerging the paver blocks in 2% diluted H_2SO_4, HNO_3, $MgSO_4$, and Na_2SO_4 for 90 days.

OPC 43 grade cement fulfilled the requirement of IS 8112:2013, of UltraTech brand, was used. Table 1 shows the chemical composition of cement having specific gravity 3.16.

RHA used in experiments met the requirements of ASTM 618C. The amount of silica was more than 80% and classified as 'F' class pozzolanic materials. It was collected from the rice mill and crushed in a ball milling machine for one hour. The particles of RHA were of uniform size and shape. The specific gravity of RHA was found to be 1.49. Table 1 shows the chemical composition of RHA.

The Maize Cob ash was obtained by burning cobs in an open furnace for 1100 ^{o}C temp, after cooling, it was crushed in a ball milling machine for one hour. Specific gravity was found to be 1.62. The chemical composition is shown in Table 1.

Two types of aggregates, fine aggregate, and coarse aggregates were used in experiments which met the requirements of IS 383- 1970. The specific gravity, water absorption, and finesse modulus of coarse aggregates were found to be 2.75, 0.77%, and 5.68 respectively. The specific gravity, water absorption, and finesse modulus of fine aggregates were found to be 2.8, 0.60%, and 2.985 respectively of Zone - II.

For RHA, the sum of SiO_2, Al_2O_3, and Fe_2O_3 is more than 70%, this indicates the pozzolanic property of the material. If classified as 'F' class pozzolana. For MCA, the sum of these major parameters is 33.35% indicating that RHA is better pozzolanic material than MCA. MCA therefore can act as filler material.

Mix design

M35 concrete mix was designed as per IS 10262:2009 code. The mix design ratio was found to be 1:1.78:2.97 with 0.43 as water – cement ratio for zero to 25mm low slump value. Since the casting of these paver blocks was to be done in a laboratory and open moulds low slump was required. Five number of MR mix concretes were designed by replacing cement with RHA and MCA at various levels like MR- 0 as 0% RHA and 0% MCA, MR-1 as 10% RHA and 2.5% MCA, MR-2 as 10% RHA and 5% MCA, MR- 3 as 10% RHA and 7.5% MCA and MR- 4 as 10% RHA and 10% MCA. Details of various concrete mixes are presented in Table 2.

Casting, Curing, and Testing of Paver Blocks

Nine, I- shaped Paver blocks of 120 mmx 100 mm x 60 mm size for each mix were cast. All the moulds of paver blocks were greased before filling the concrete mix. Vibrating table was used for uniform filling and blocks were kept under wet jute bags for 24 hrs. After 24 hrs., paver blocks were demolded and cured in potable water for 7, 28, and 56 days. After the curing age, paver blocks were taken out from the water tank and wiped in cotton cloth. Rebound hammer test values thus measured have been tabulated in Table 3.And a load was gradually was applied under the UTM (Universal Testing Machine) to determine for compressive strength as shown in Table 4. A slump test was performed before casting the paver blocks. It was found that the values varied from 0 mm to 25 mm.

Results and Discussion

Compressive Strength of Paver Blocks

From Table 3 and 4 it was observed that rebound hammer value and compressive strength increase with the increase in age in all the cases. However, the values decreased with the increase in the amount of ashes. The control mix concrete (MR-0) maintained maximum strength as compared to other MR mix at all the ages. Large variation in strength was found between 7 and 28 days strength while minor increment was found in 56 day strength. This might have happened due to the presence of MCA, which had little pozzolana property. According to Bapat, (2012) and Shetty, (2005), firstly MCA acted as filler in concrete. After that SiO_2 present in ashes reacted with $Ca(OH)_2$ and formed CSH – II and provided strength to the concrete. For MR-1 and 2 concrete, the 28 days compressive strength was found to be $44 N/mm^2$ which was more than the target mean strength $43.25 N/mm^2$.

Table 1. Chemical composition of OPC 43, RHA and MCA

	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	MgO	SO_2	K_2O
OPC 43	20.58	4.98	3.89	57.21	0.15	1.27	2.54	0.57
RHA	85.48	3.04	0.45	2.36	0.08	0.56	0.75	1.7
MCA	28.02	4.39	0.94	2.75	0.15	1.02	1.48	5.03

Table 2. Details of mix proportions (kg/m^3)

Concrete Mix	Cement	Fine Aggregate	Coarse Aggregate	RHA	MCA	Water
MR-0	406.604	722.403	1208.072	-	-	174.840
MR-1	355.779	722.403	1208.072	40.660	10.165	174.840
MR-2	345.613	722.403	1208.072	40.660	20.330	174.840
MR-3	335.449	722.403	1208.072	40.660	30.495	174.840
MR-4	325.284	722.403	1208.072	40.660	40.660	174.840

Therefore, 10% RHA and 5% MCA was considered as optimum replacement level of cement in M35 grade concrete for I – Shaped paver blocks.

The above fact that RHA provides pozzolanic reaction and MCA acts as filler can be confirmed from Tables 3 and 4. There is an increase of even more than 100% in both rebound hammer values and compressive strength between 7 and 28 days.

Table 3. Rebound Hammer values

Concrete Mix	7 days	28 days	56 days
MR-0	18	20	22
MR-1	13	18.5	21.8
MR-2	10	17.6	20.5
MR-3	9	15	18
MR-4	8	12.5	14

Table 4. Compressive Strength (N/mm^2)

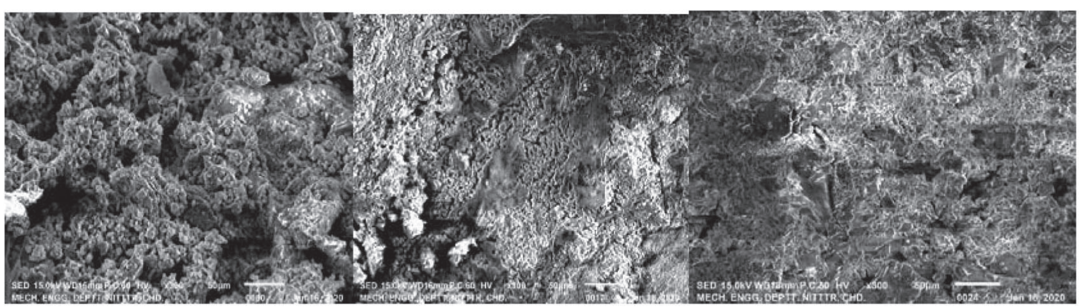
Concrete Mix	7 days	28 days	56 days
MR-0	31.50	45.40	48.00
MR-1	29.00	44.60	46.90
MR-2	20.20	44.00	45.70
MR-3	15.00	39.80	41.30
MR-4	13.80	34.00	35.00

However, there seems to be an optimum balance in the RHA and MCA contents as the increase in strength was very marginal for MR-3 and MR-4 specimens between 28 and 56 days indicating that pozzolanic reaction dominated in MR-1 and MR-2. These specimens could also achieve target strength. Therefore, the observations related to durability were made with MR-2 specimens as this included maximum MCA which also achieved target compressive strength.

Scanning Electron Microscope (SEM) of concrete

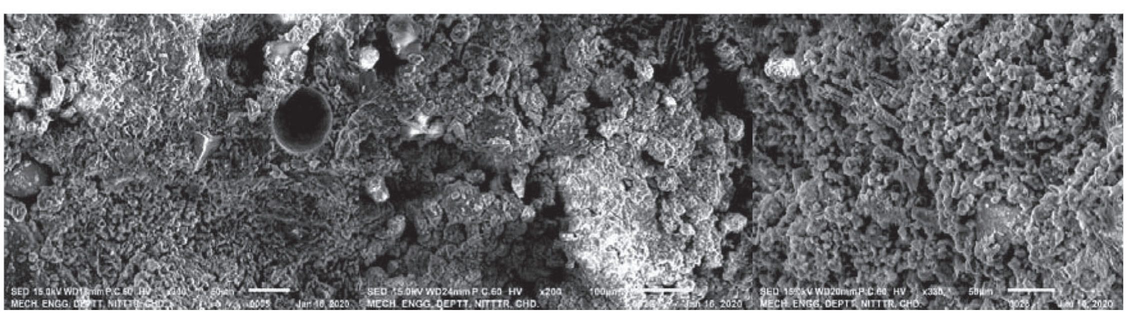
Fig.1 (a) shows, control mix concrete hydration reaction has been started and formation of ettringite are visible. Very less amount of silica is also present. After 28 days of curing calcium silicate hydrated gel is formed and interfacial transition zone formation is visible in Fig.1(c). On 56 days of curing all the cement is hydrated and concrete become dense.

Fig. 2(a) shows the formation of carbon particles of Maize cob and rice husk ash, silica in bright portion of and hydration of cement is visible. Fig. 2(b), after 28 days of curing ettringite formed and silica is present. Fig. 2(c) 56 days, cement has been hydrated and hydrated calcium silicate formed.



(a) (b) (c)

Fig. 1.(a) 7days; 1(b) 28 days ; 1(C) 28 days SEM image of Control Mix Concrete



(a) (b) (c)

Fig. 2.(a) 7days; 1(b) 28 days ; 1(C) 28 days SEM image of MR Concrete (MR-0)

Durability Properties

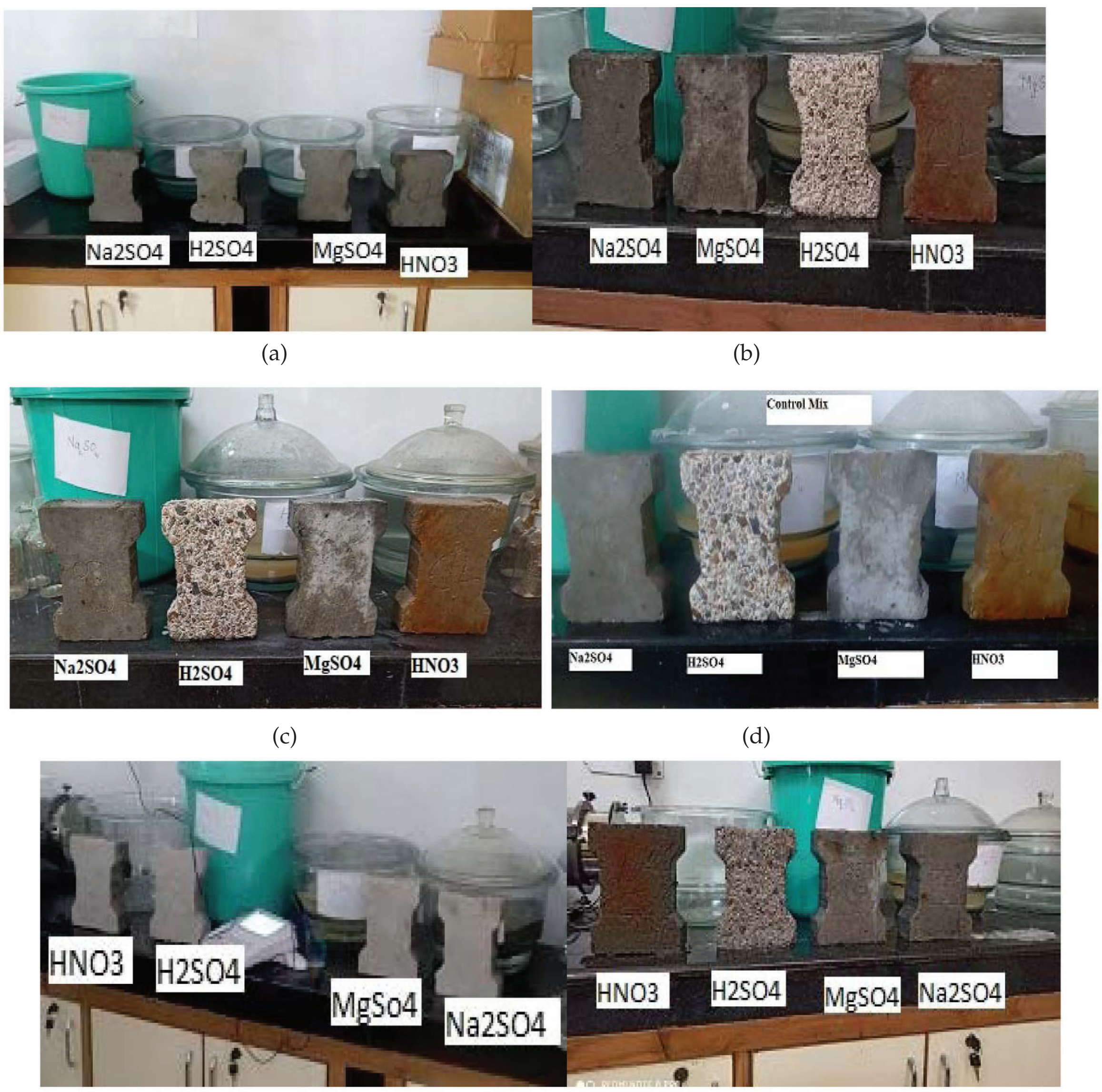
For the durability test of concrete, 28 days cured paver blocks were submerged in the 2% diluted chemical solutions after 28 days curing in water. Changes in weight, dimensions, appearance, and compressive strength were assessed were made after 30, 60, and 90 days.

Visual Assessment of MR-0 Concrete

After 30 days as shown in Fig. 3(a) and (b), it was found that the upper layer of the controlled concrete paver block has been removed and aggregates of the concrete were visible when dipped in H_2SO_4 solution. HNO_3 dipped paver blocks got rust colored appearance. $MgSO_4$ dipped paver blocks showed the white colored powder deposited on the upper layer. There was no change found in the paver block dipped in Na_2SO_4 solution. All such changes became more apparent and prominent after 60 and 90 days shown in Fig 3(c) and (d).

Visual Assessment of MR-2 Concrete

After 30 days shown in Fig. 4(a) and 2(b), MR-2 concrete paver blocks showed that the upper layer of concrete has been removed and aggregates were



(a) (b) (c) (d) (e) (f)

Fig. 3. Control Mix concrete (MR-0) Paver Blocks after (a) 0 days; (b) 30 days; (c) 60 days; (d) 90 days

visible very clearly in the H_2SO_4 solution. The rust powder has appeared on HNO_3 dipped block. Very small area was covered with white deposition on $MgSO_4$ dipped paver block. No change was found on the Na_2SO_4 paver block. These observations were furthermore apparent after 60 and 90 days curing Figs. 4 (c) and (d).

Color

As shown in Fig 3, it was observed that the color of the MR-0 control mix concrete was white throughout the paver block while MR-2 concrete was dark gray, and white deposition were found at some places in the paver block.

Change in Weight, Length, thickness, Rebound Number Values and Compressive Strength of Paver Blocks

Tables 5(a) & (b) – 9 show the change in the weight, dimensions, and compressive strength of the paver blocks dipped for 30, 60, and 90 days in HNO_3, $MgSO_4$, H_2SO_4, and Na_2SO_4 chemical solutions.

HNO_3 Submersed Paver Blocks

From the results shown in Tables 5(a) and (b) it was found that up to 60 days submersed control mix paver block did not show any change in weight but after 90 days it increased up to 260 g. Length shrunk from 1.28 mm to 3.1 mm after 30 to 90 days, respectively while thickness shrunk from 0.04 mm to 2.54 mm respectively after 90 days. Rebound Hammer (RBH) number reduced 12% from after 90 days of submersion. Compressive strength of 90 days submersed paver block was found to be 42N/mm^2 which was less than the MR-0 control mix concrete (45.4N/mm^2) cured 28 days in water.

The MR-2 paver block showed loss in weight to 140 gram after 90 days. Length shrunk to 0.15 mm and thickness to 4.18 mm after 90 days, respectively. The Rebound Hammer (RBH) number decreased from 18 to 12 after 90 days of submersion. Compressive strength of 90 days submersed paver block was found to be 23 N/mm^2. It was less than the 28 days cured in water paver block having 44N/mm^2.

It happened due to nitric acid solution, calcium

(a) (b)

Fig. 4. Control Mix concrete (MR-0) Paver Blocks after (a) 0 days; (b) 30 days; (c) 60 days; (d) 90 days

(a) (b)

Fig. 5. (a) MR -2 Paver Block; (b) MR-0 Paver Blocks submersed in the H_2SO_4 solution for 60 days.

nitrate was formed during the reaction of calcium hydroxide and nitric acid in concrete which further reacted with gypsum to produce calcium nitroaluminate hydrate (aq.) as shown in Eqs. 1&2 (Olusola and Joshua, 2012).

$$2HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2.\ 2H_2O \quad ..\ (1)$$

$$Ca(NO_3)_2.2H_2O + 3CaO.Al_2O_3.8H_2O \rightarrow 3CaO.Al_2O_3.Ca(NO_3)_2.10H_2O \quad ..\ (2)$$

Calcium nitroaluminate hydrate (aqueous) leached out deposited on surface of the blocks causes shrinkage. Some pores created during this process might be filled water causing some enhancement in weight.

In MR-2 paver block calcium hydroxide was less compared with the controlled mix. Therefore the leaching was less yet the formation of CSH gel was also less. MR-2 paver block were having major losses in weight, length and thickness.

H_2SO_4 submersed Paver Blocks

The weight H_2SO_4 submersed control mix paver

Table 5(a) and (b). Change in Weight (kg) of Paver Blocks

Control Mix Paver Blocks							
Chemical	Initial Wt.	After 30 days Wt.	Change Wt. %age	After 60 days Wt.	Change Wt. %age	After 90 days Wt.	Change Wt. %age
HNO_3	4.14	4.14	No change	4.14	No change	4.40	Gain (1.44)
H_2SO_4	4.23	4.16	Loss (1.65)	4.09	Loss (3.30)	4.09	Loss (3.30)
$MgSO_4$	4.17	4.20	Gain (0.71)	4.20	Gain (0.71)	4.46	Gain (6.95)
Na_2SO_4	4.10	4.13	Gain (0.73)	4.13	Gain (0.73)	4.39	Gain (7.07)

(a)

MR-2 Paver Blocks							
Chemical	Initial Wt.	After 30 days Wt.	Change Wt. % age	After 60 days Wt.	Change Wt. % age	After 90 days Wt.	Change Wt. %age
HNO_3	4.05	4.02	Loss (0.74)	4.02	Loss (0.74)	3.91	Loss (3.45)
H_2SO_4	3.98	3.95	Loss (0.50)	3.95	Loss (0.75)	3.92	Loss (1.50)
$MgSO_4$	4.04	4.06	Gain (0.49)	4.06	Gain (0.49)	4.08	Gain (0.99)
Na_2SO_4	4.02	4.04	Gain (0.49)	4.04	Gain (0.49)	4.06	Gain (0.99)

(b)

Table 6 (a) and (b). Change in length (mm) of Paver Blocks

Control Mix Paver Blocks							
Chemical	Initial	After 30 days	Change %age	After 60 days	Change %age	After 90 days	Change %age
HNO_3	199.82	198.54	Loss (0.14)	198.52	Loss (0.65)	196.52	Loss (1.65)
H_2SO_4	199.81	199.74	Loss (0.03)	199.63	Loss (0.09)	196.20	Loss (1.80)
$MgSO_4$	199.42	199.31	Loss (0.05)	199.30	Loss (0.06)	198.32	Loss (0.55)
Na_2SO_4	198.82	198.94	Gain (0.06)	198.95	Gain (0.11)	197.98	Gain (0.80)

(a)

MR-2 Paver Blocks							
Chemical	Initial	After 30 days	Change %age	After 60 days	Change %age	After 90 days	Change %age
HNO_3	199.93	199.83	Loss (0.05)	199.81	Loss (0.06)	199.78	Loss (0.07)
H_2SO_4	199.89	199.73	Loss (0.08)	199.71	Loss (0.09)	199.61	Loss (0.14)
$MgSO_4$	199.22	199.20	Loss (0.01)	199.48	Gain (0.13)	199.50	Gain (0.14)
Na_2SO_4	198.82	198.90	Gain (0.04)	198.92	Gain (0.05)	198.94	Gain (0.20)

(b)

block reduced by140 g, the length and thickness reduced by 3.61 mm and 1.27 mm, respectively after 90 days of submersion. The RBH value also decreased to 8.8 numbers from 21.8. Compressive strength was found to be 28 N/mm^2 as compared to 28 days dipped in water paver block of 44.5N/mm^2.

MR concrete paver block weight decreased 50 g. While reductions in length and thickness were 0.28 mm and 0.31mm respectively. The RBH value reduced by 4 numbers from 19. Compressive strength was found to be 36.2 N/mm^2 with respect to the 28 days water dipped paver block having strength of 44N/mm^2.

When paver block was dipped in H_2SO_4, It was observed that upper layer of paver block was separated and aggregates appeared on the surface which led to decrease in weight. The gypsum present in cement reacted with sulfuric acid and led to swelling of top layer causing splitting which reduced the length of paver block. Similar observations were found by (Joorabchian, 2010) with the reasons shown in eqs. 3 to 5.

Table 7(a) & (b). Change in thickness (mm) of Paver Blocks

Control Mix Paver Blocks							
Chemical	Initial	After 30 days	Change %age	After 60 days	Change %age	After 90 days	Change %age
HNO_3	67.64	67.63	Loss (0.014)	67.60	Loss (0.05)	65.10	Loss (3.75)
H_2SO_4	68.33	68.12	Loss (1.79)	67.10	Loss (1.74)	67.06	Loss (1.86)
$MgSO_4$	66.24	64.53	Loss (2.58)	64.48	Loss (2.65)	64.48	Loss (2.65)
Na_2SO_4	67.21	67.40	Gain(0.29)	66.41	Gain(0.30)	67.45	Gain(0.35)

(a)

MR-2 Paver Blocks							
Chemical	Initial	After 30 days	Change % age	After 60 days	Change %age	After 90 days	Change %age
HNO_3	69.48	69.10	Loss (0.54)	66.32	Loss (4.54)	65.30	Loss (6.01)
H_2SO_4	67.33	66.10	Loss (1.82)	65.30	Loss (3.01)	67.02	Loss (0.46)
$MgSO_4$	66.23	66.20	Loss (0.04)	66.60	Gain (0.56)	66.70	Gain (0.71)
Na_2SO_4	68.72	68.80	Gain (0.11)	68.84	Gain (0.17)	68.92	Gain (0.29)

(b)

Table 8 (a) and (b). Rebound Hammer no. of Paver Blocks

Control Mix Paver Blocks					
Chemical	Initial	After 30 days	After 60 days	After 90 days	Change %age
HNO_3	20.5	20	20	18	Loss (12)
H_2SO_4	21.8	20	16	13	Loss (40)
$MgSO_4$	20.0	20	22	22	Gain (10)
Na_2SO_4	21.6	22	22.5	24	Gain (11)

(a)

MR Concrete Paver Blocks					
Chemical	Initial	After 30 days	After 60 days	After 90 days	Change %age
HNO_3	18	15	10	12	Loss (33)
H_2SO_4	19	16	15	15	Loss (21)
$MgSO_4$	18.5	19	20	20.5	Gain (11)
Na_2SO_4	18	18	19	19	Gain (5)

(b)

$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4.\ 2H_2O$ .. (3)

$3CaO.2SiO_2.2H_2O + H_2SO_4 \rightarrow CaSO_4.2H_2O + Si(OH)_4$ .. (4)

$CaO.SiO_2.2H_2O + H_2SO_4 \rightarrow CaSO_4 + Si\ (OH)_4 + H_2O$ .. (5)

Due to this reduction in weight, length, thickness and strength were observed in both control mix paver block and MR-2 paver block. The reduction in these parameters were less in MR-2 paver block because $Ca(OH)_2$ produced during hydration reaction was used to form secondary CSH-II (calcium silicate hydrate). Therefore less amount of calcium hydroxide was available to react.

$MgSO_4$ submersed Paver Blocks

The weight of $MgSO_4$ submersed control mix paver block increased by 290 g in 90 days. Shrinkage in length and thickness were observed 0.10 mm and 1.76 mm respectively in 90 days. RBH number was increased 20 to 22. Compressive strength was found to be 31.8N/mm^2 which was less than the MR-0 control mix concrete (45.4N/mm^2) cured 28 days in water.

MR concrete weight increased 40 g in 90 days. Expansion in length and thickness were 0.28 mm and 0.47 mm respectively. RBH number increased from 18.5 to 20.5. Compressive strength was found to be 37.5 N/mm^2 with respect to the 28 days water dipped paver block having strength of 44N/mm^2.

When $MgSO_4$ solution reacts with $Ca(OH)_2$ of hydrated cement and produced gypsum and brucite. This brucite, insoluble in nature has destabilized the calcium silicate hydrate and produced Magnesium silicate hydrate (MSH) as shown in eq. In control mix paver block, the magnesium ion replaces the calcium ion from calcium silicate hydrate and produce MSH. It is responsible for reduction in strength and expansion of concrete. The formation of brucite provides a protective layer which decelerates the further reaction. Therefore gain in weight and expansion was observed in both control mix concrete shown in eqs. 6 – 8 (Maes and Belie, 2017).

Table 9. Compressive Strength (N/mm^2) of Paver Blocks

Chemical	Final Str. of Control Mix concrete	Final Str. of MR Concrete
HNO_3	42	23.4
H_2SO_4	28	36.2
$MgSO_4$	31.8	37.5
Na_2SO_4	41	43.7

$MgSO_4 + Ca(OH)_2 \longrightarrow CaSO_4\ .\ 2H_2O + Mg(OH)_2$ .. (6)

$MgSO_4 + C-S-H \longrightarrow CaSO_4.\ 2H_2O + M-S-H$ .. (7)

OR

$C_3S_2H_8 + 3MSH \longrightarrow 3CSH_2 + 2SiO_2\ aq. + 3MH_2 + 17H$ .. (8)

While MR-2 paver block observed slight more expansion in length and weight as compared to control mix MR-0 paver block because calcium hydroxide was not available for the reaction therefore MSH was produced in less amount and the retained strength was better.

Na_2SO_4 submersed Paver Blocks

Increment in weight (290 g) was observed by the Na_2SO_4 dipped control mix paver block after 90 days. Expansion in length and thickness take place up to 0.16 mm and 0.24 mm respectively in 90 days. RBH number was increased 2.4 numbers. While compressive strength was 41N/mm^2 for control mix paver block which was less than the MR-0 control mix concrete (45.4N/mm^2) cured 28 days in water.

The weight of MR concrete paver blocks increased up to 40 g. Expansion in length and thickness took place up to 0.12 mm and 0.20 mm respectively in 90 days. RBH number was increased 1 numbers .While compressive strength was 43.7N/mm^2 for control mix paver block with respect to the 28 days water dipped paver block having strength of 44N/mm^2.

With Na_2SO_4, Calcium hydroxides was reacted and very less change were observed in both control mix and MR-2 paver block due to un - stabilization of paver block.

$CH + N_2SH_{10} \longrightarrow CSH_2 + 2NH + 7H$ .. (9)

$2C_3AH_6 + 3N_2SH_{10} \longrightarrow C_3A._3CSH_{32} + 2AH_3 + 6NH + 5H$ .. (10)

$C_3S_2H_8 + 3N_2SH_{10} \longrightarrow 3CSH_2 + 2SiO_2.aq + 6NH + 20H$ .. (11)

Due to the formation of sodium hydrate (NH) and expansion of gypsum resulted in minor enhancement in weight and dimension of paver blocks as shown in eqs. 9 – 10 (Oymael and Sen, 2008).

Overall expansion in $MgSO_4$ attack was less than Na_2SO_4 attack due to different mechanism. In Na_2SO_4 deterioration occurred due to expansion was associated with ettringite while in $MgSO_4$, attack was related to decomposition of Calcium Silicate Hydrate (CSH) (Siddique and Khan, 2011).

Conclusion

From the above study it is concluded that Maize Cob and Rice Husk ash concrete can be used as partial replacement of cement in concrete with (10% RHA + 5% MCA), MR-2 paver has shown good resistance against sulfuric acid. Hence, these blocks may be suitable in lawns and parks and in industrial areas where decomposition of organic material may emit in large amount of hydrogen sulfide gas, which reacts with moisture present in environment and form sulfuric acid. This leads to swelling in upper layer of concrete which splint out and reduce the strength of control mix concrete. This MR concrete can be used in lawns, open area, parking areas, low traffic areas, houses and for manufacturing of perforated blocks / grass concrete paving / permeable paving where vegetation or grass can gross can be used in low traffic area, parking and in houses.

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Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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